The SAM Hydraulic Design Package for Channels evolves into SAMwin

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Abstract

SAMwin, now available, is the SAM Hydraulic Design Package for Channels with a Windows-based graphical user interface. It is the SAM that users have become familiar with over the 15 years since its inception but with a new interface. The flow of input and the output in SAMwin is readily recognizable to current SAM users, and easily followed by new users.

SAM is an integrated system of programs developed through research over the past 15 years. Applicable equations from the latest research have consistently been coded into the applicable SAM element. The hydraulics module, SAM.hyd, calculates normal depth and composite hydraulic parameters from distributed roughness, using several bed roughness predictors. It will also calculate stable channel dimensions – channel width, depth, and slope – while conserving sediment continuity. These calculations use analytical equations which include bed material transport and which separate total hydraulic roughness into bank and bed components. Given either velocity and discharge or discharge and a cross section shape, SAM.hyd will calculate riprap size using the standard Corps procedure. It will also calculate meander geometry based on a sine curve. The sediment transport module, SAM.sed, calculates bed material discharge curves using sediment transport theories. Currently, 20 sediment transport functions are available. The sediment yield module, SAM.yld, calculates sediment yield using the Flow-Duration Sediment-Discharge Rating Curve Method. SAM.aid provides guidance in the selection of the most applicable sediment transport function(s) to use with a given project, based on five screening parameters: d_{50}, slope, velocity, width, and depth.

Now users can apply SAM with the convenience of an interactive, Windows-based interface. This makes the package more easily accessible by engineers involved in stream restoration projects, flood control projects and assessing the magnitude of sediment problems in hydraulic design work.

This paper will present both an overview of SAM's capabilities and an introduction to the SAMwin Hydraulic Design Package for Channels.

Summary of SAM Capabilities.

SAM was designed to aid engineers in analyses associated with designing, operating, and maintaining flood control channels and stream restoration projects; to satisfy the need for a qualitative, easy-to-use methodology for these types of analyses; and to be used in preliminary screening of alternatives where funds for more extensive investigations are not available. The SAM package is designed to provide hydraulic engineers smooth transition from making hydraulic calculations to calculating sediment transport capacity to making sediment yield determinations. The separate capabilities of the three main modules of the package can be utilized to aid in various hydraulic design situations, or the modules can be used in series, to evaluate channel stability in terms of the cost of maintaining the constructed channel.

SAM.hyd. SAM considers only one typical cross section, not a reach, of a river. However, the geometry of that cross section can be prescribed with station and elevation coordinates for irregular channels, or as a simple or compound channel for trapezoidal channels.

SAM.hyd solves the steady state, normal-depth equation to transform complex geometry into composite hydraulic parameters. The program can solve for either depth, width, slope, discharge, or roughness. It allows roughness to be calculated by several different roughness equations within the same cross-section. SAM.hyd also contains a meander algorithm which provides both curvilinear and Cartesian coordinates for a meander planform based on the sine-generated curve.

SAM.hyd contains an analytical procedure for calculating stable channel dimensions in fully alluvial sand bed or gravel bed streams. This calculation provides a table of channel width-depth-slope dimensions which are in equilibrium with the inflowing sediment load. Channel dimensions at minimum stream power are also calculated.

SAM.hyd offers two procedures for calculating riprap. When flow velocity and depth are given, the riprap size is calculated directly. When water discharge and cross section are given, riprap size is calculated as described in EM 1110-2-1601, "Hydraulic Design of Flood Control Channels" (USACE 1991, 1994).

SAM.hyd tests the results of normal depth calculations against the Shield's Diagram for particle stability to determine whether or not riprap is required, notifying the user if riprap is required.

SAM.sed. This module calculates the bed material sediment discharge rating curve by size class using hydraulic parameters either calculated in SAM.hyd or user specified. The sediment transport functions programmed into SAM.sed cover a range of riverine conditions and are listed in Table 1. Sediment transport is calculated by partitioning the mixture into size classes, calculating transport for each size class, and then summing the rates of each to get the total, except for the functions identified as “d50,” which are for a single grain size. . The SAM user’s manual, “SAM Hydraulic Design Package for Channels,” (Thomas et al., 2002) and the SAM.aid program both provide the range of data used in the development of the sediment transport functions included in SAM.sed.

Table 1. Sediment Transport Functions in SAM

Ackers-White	MPM (1948), d50
Ackers-White, d50	Parker [gravel only]
Brownlie, d50	Profitt (Sutherland)
Colby	Schoklitsch
Einstein (Bed-Load)	Toffaleti
Einstein (Total-Load)	Toffaleti-MPM
Engelund-Hansen	Toffaleti-Schoklitsch
Laursen (Copeland)	Yang
Laursen (Madden), 1985	Yang, d50
Meyer-Peter And Muller (MPM), 1948	Van Rijn

It is important to note that SAM.sed applies the sediment transport functions at a point, thus allowing for no temporal or spatial variability in the size class distribution.

Importance of bed-material gradation designation. In the calculation of sediment transport, the designated bed gradation controls the calculated sediment discharge. The rate of transport increases exponentially as the grain size decreases, as shown in Figure 1. Therefore, bed-material gradations must be determined carefully. Techniques for selecting a representative sample are discussed in EM 1110-2-4000 (USACE 1989). Appendix D in "Hydraulic Design of Stream Restoration Projects" (Copeland et al. 2001) is a thorough treatment of bed material considerations (**http://libweb.wes.army.mil/uhtbin/hyperion/CHL-TR-01-28.pdf**).

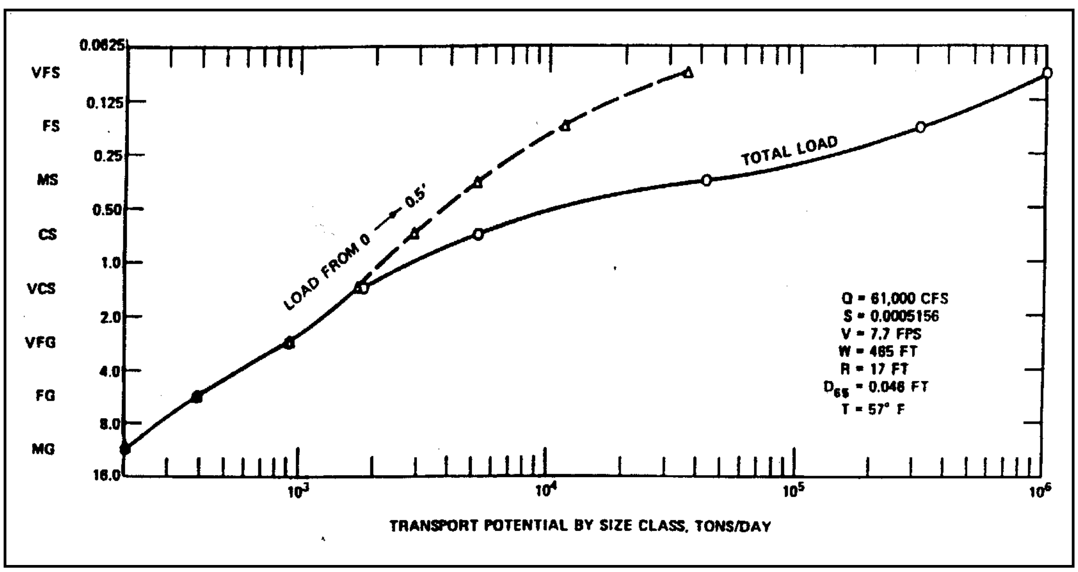

Figure 1. Variation of sediment transport with grain size (from EM 1110-2-4000 (USACE 1989), Figure 10-7)

SAM.yld. SAM.yld calculates the sediment yield passing a cross-section during a specified period of time, which can be a single flood event or an entire year. The flow can be specified by either a flow duration curve or a hydrograph. The sediment discharge rating curve can be specified as either sediment discharge or sediment concentration versus water discharge.

SAM.yld provides hydraulic design engineers a systematic method for rapidly calculating sediment yield. Sediment yield is the total sediment outflow from a watershed or drainage basin, measurable at a cross section of reference and in a specified period of time (ASCE, 1975). Sediment yield can be subdivided based on the method of transport. The finer portion of the sediment yield continuously maintained in suspension by flow turbulence is called washload. The coarser fraction of the sediment yield actively exchanged with the sediment on the bed is called the bed-material sediment yield. If sediment transport is calculated using sediment transport *equations*, only the bed-material sediment yield is calculated. If sediment transport is determined from total load *measurements*, then the total sediment yield (washload and bed-material load) is calculated.

SAM.yld integrates the flow duration curve with the sediment discharge rating curve. This method, the "Flow-Duration Sediment-Discharge Rating Curve method" described in EM 1110-2-4000 (USACE 1989), is widely used in the Corps of Engineers for two reasons. First, both the flow duration curve and the sediment discharge rating curve are process-based and can be changed from the historical values needed for hindcasting to values needed for forecasting water and sediment yield in the future. Also, the curves can be defined to reflect specific components of the sediment runoff process, i.e., a sediment discharge rating curve can be calculated for sand and gravels when those are the types of sediment of most interest to project performance.

Sediment discharge rating curve. The sediment discharge rating curve needed for SAM.yld is calculated in SAM.sed in terms of sediment concentration. However, the sediment discharge rating curve may be described in terms of tons/day and input manually. If total sediment yield is required, the sediment discharge rating curve must be determined from measurements and manually input to SAM.yld, since SAM .sed calculates the bed-material sediment discharge rating curve.

Flow duration curve. The flow duration curve is a relationship between water discharge and the cumulative frequency each discharge occurs over a given time. It is a graphic description of a hydrologic event. The discharge magnitudes are plotted as the ordinates with the corresponding percents of time exceeded as the abscissas. Care should be taken in developing this curve.

Points of caution. SAM is not a package of one-dimensional models. SAM makes calculations based on one cross section at one point in time. There are no provisions in any of the modules for simulating unsteady flow effects nor for looking at a reach of a river, except as it might be represented by a typical section. Sediment transport functions in SAM must be used with care. Considering that the size class distribution of bed material in the natural river changes with discharge, reach, time of year, and other temporal factors, SAM's use of a fixed, non-varying, as-prescribed size class distribution for all calculations presents the possibility that the calculated transport rates are not truly representative of the natural river. However, SAM will provide reasonable answers if the user is cognizant of the need to carefully prescribe the bed material gradation.

Water temperature variations when coupled with seasonal changes in land use may require that separate warm and cold weather sediment discharge rating curves be used to achieve acceptable accuracy in the calculated results. Care must be taken when extrapolating a sediment discharge rating curve to water discharges well above the range of measured data.

The sediment discharge rating curve, plotted as water discharge (Q) versus sediment discharge (QS) on a log-log grid, typically has significant data scatter, which demonstrates that sediment discharge is not a simple function of water discharge. The engineer should investigate and evaluate any regional and watershed characteristics which might contribute to scatter. In flashy streams, using only mean daily data will underestimate sediment yield. To ensure reasonable results the peak discharges of record should be incorporated into the flow duration curve, or the hydrograph, used in SAM.yld.

The New Interface

SAMwin, and support for it, is available to Corps offices free with participation in the Numerical Model Maintenance Fund. Due to CRDA-01-CHL-04 with Owen Ayres and Associates, Inc., these copies are to be used only by Corps personnel. Other government offices, contractors, and private firms may purchase the package, and support, directly from Ayres Associates, 3665 John F. Kennedy Parkway, Building 2, Suite 200, Fort Collins, CO, 80525, 970-223-5556; schallj@ayresassociates.com.

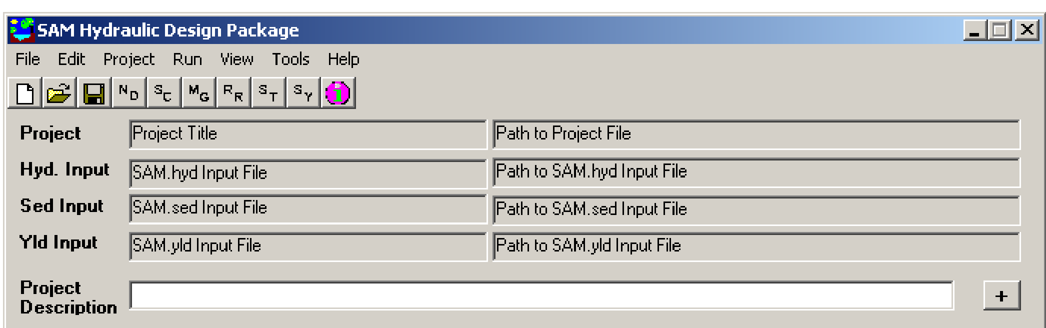

Figure 2. Opening window of SAMwin.

The SAM users manual (Thomas et al., 2002) provides detailed descriptions of working in the new interface, as well as the theoretical bases for the computations. The following will be a brief overview of the new interface.

The input screens for SAMwin were designed with the HEC-RAS screens in mind, knowing that many Corps users are familiar with that package. Figure 2 shows the opening window for the program.

Each of the items on the menu bar has a drop-down menu. “File” offers the standard items. “Edit” offers the user the choice of editing hydraulic, sediment transport or sediment yield input files. “Project” allows the user to add input files. “Run” is a method of running one of the calculation modules on a user-specified input file, on that was not necessarily input through SAMwin. “View” will open an input or output file. “Tools” offers HECDSSVue, which does not come with the SAM package, for plotting and SAM.aid. “Help” provides access to the complete user’s manual (Thomas et al., 2002).

A project must be set up before a data file can be made or edited. It is mandatory that no spaces appear in the pathname to the working subdirectory or in the data filename. Then, to create or edit a data file, select Edit from the screen in figure 2 and choose the type file to work on, see figure 3. If an input file (*.hi for SAM.hyd, *.si for SAM.sed, or *.yi for SAM.yld) exists in the specified project directory, then that file will automatically be read and its data will appear in the appropriate window.

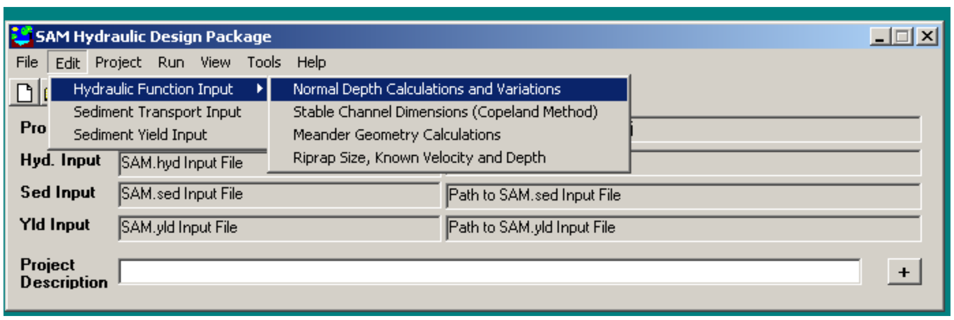

Figure 3. Hydraulic function input file choices.

SAM.hyd. The Hydraulic Function Input menu item offers further choices of input file type, as shown in figure 3.

Choosing Normal Depth Calculations and Variations brings up the screen shown in figure 4. Inputting title records is optional. The Calculation Options area allows the user to select the hydraulic parameter to be calculated (normal depth, bottom width, energy slope, hydraulic roughness, and water discharge), the compositing method to use (alpha, equal velocity, total force, and conveyance), and the type geometry to input [simple channel (single trapezoidal channel), compound channel (up to three, ‘stacked,’ trapezoidal channels), and station-elevation].

The Flow Data area allows the user to easily input the water discharge, water surface elevation, slope and temperature, up to ten values each. Geometry can be input through one of the channel template windows, figure 5, or through the “Cross Section Input” window, figure 6. If water discharge or energy slope were selected as the “Variable to Calculate” and data is entered for that variable in the “Flow Data” area, SAM will ignore that data. Once a complete data set is input the “Solve” button becomes active. If the Display Entire Output File box is checked, when calculations are complete the output file will open in its own window, using Notepad. If this button is not checked, some input will echo to the screen in an area that will drop down below this entire window.

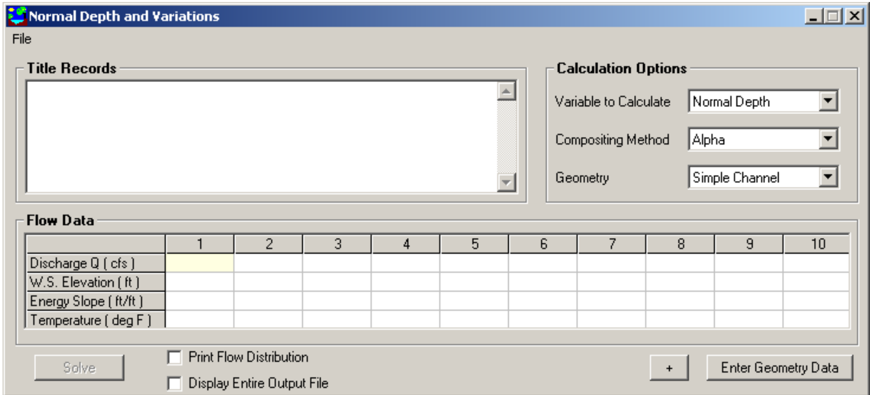

Figure 4. Normal Depth and Variations window.

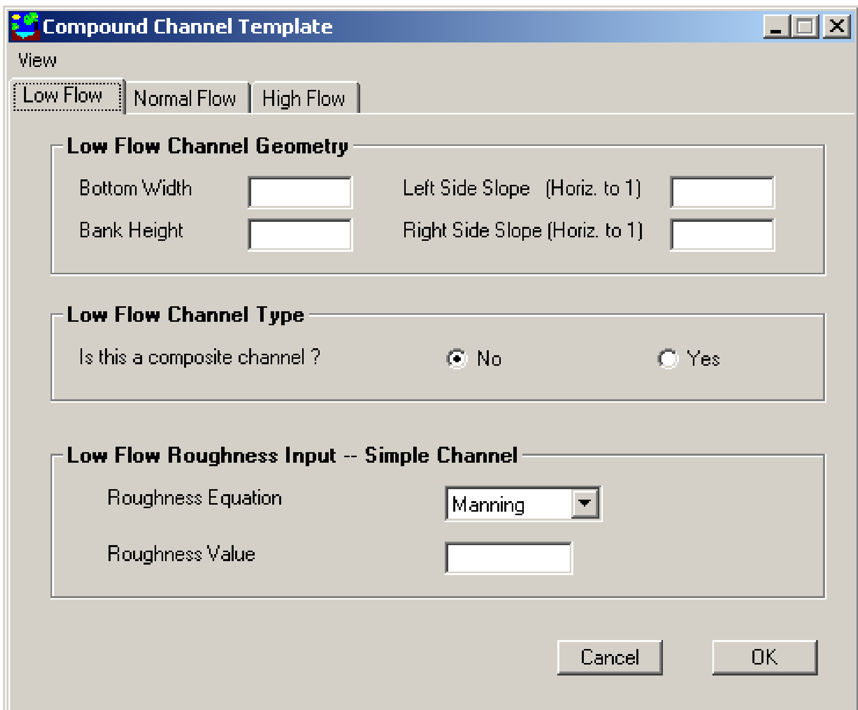

Figure 5. The Compound Channel Template, including the bed material gradation input area.

SAM.sed. The input window for SAM.sed is shown in figure 7. If this option is chosen after making hydraulic calculations, the results of those calculations will automatically appear on the screen. Clicking on “Enter Bed Material Data” brings up a window much like the “Bed Material Data” area in figure 6. A check in the box by a sediment transport function will cause SAM.sed to make those calculations. Any or all functions can be checked in a data set. Other areas work similarly to those shown in figure 4.

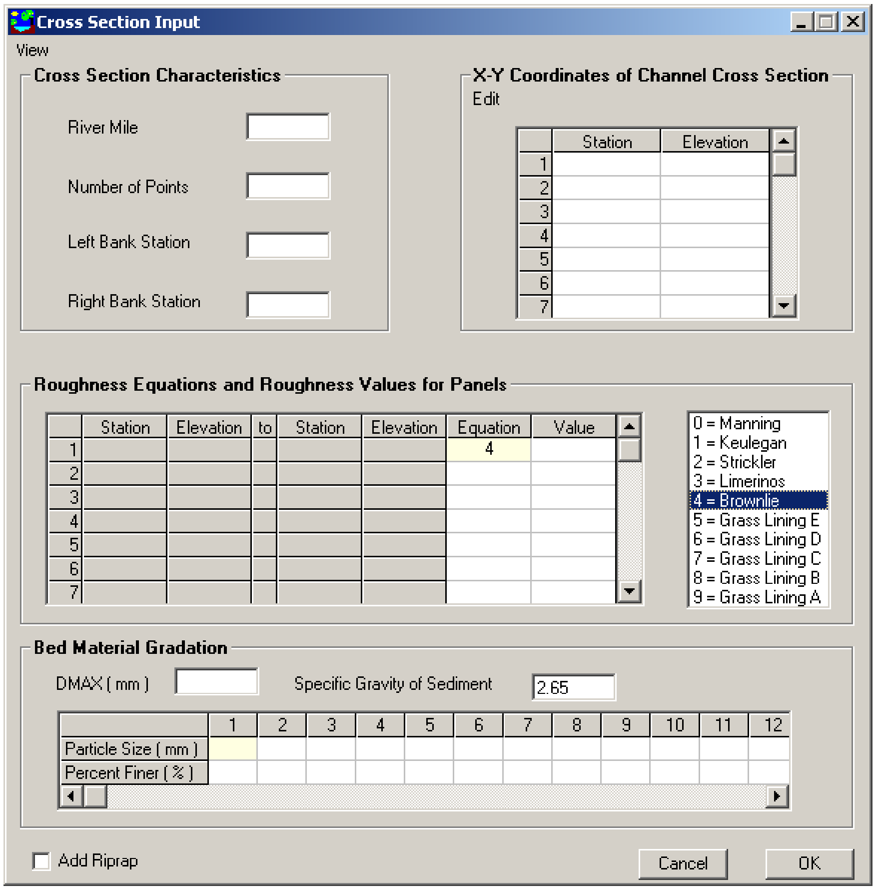

Figure 6. Station-elevation geometry input window, showing the bed gradation input area (appears when the Brownlie (4) or Limerinos (3) equations are selected).

SAM.yld. SAM.yld will accept either a flow hydrograph, figure 8, or a flow duration curve, figure 9. Note that the Optional Data area changes depending on the type of flow input. The sediment discharge rating curve data, in the *.yi file, will not appear on a screen, but can be viewed, and changed if desired, by using the SAM main menu View option and selecting SAM.yld input.

General. The SAM package is a product of the Flood Damage Reduction and Stream Restoration Research Program. The conception and initial development of the package were the results of the efforts of William A. Thomas, Ronald R. Copeland and Nolan Raphelt. However, many workunits and many principal investigators have contributed to the package. The US Government is not responsible for results obtained with this software. However, the office supporting the package would welcome documentation of program errors and should respond if fiscally feasible.

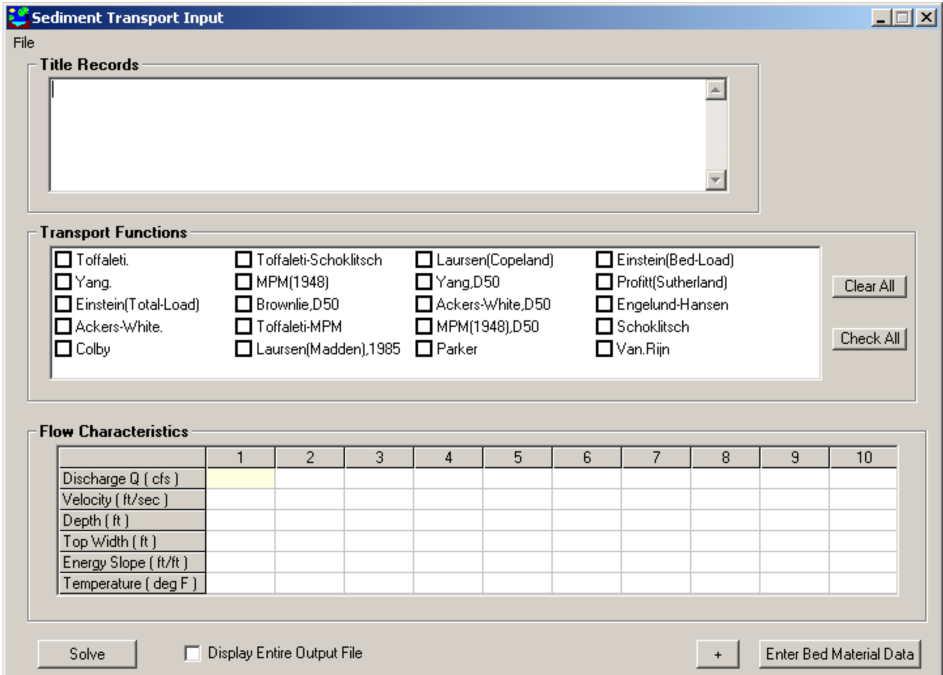

Figure 7. SAM.sed input screen.

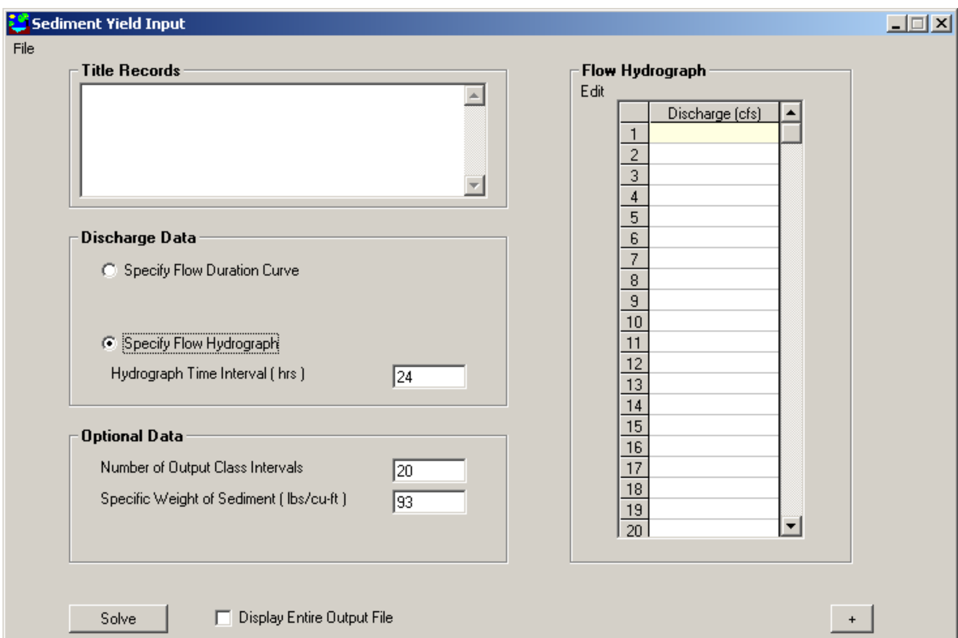

Figure 8. The Sediment Yield Input window for hydrograph data.

Conclusions. The SAM Hydraulic Design Package for Channels that many Corps districts have come to rely on is now available with a user-friendly graphic interface. The calculation modules the new SAMwin uses are the same as those used in DOS mode.

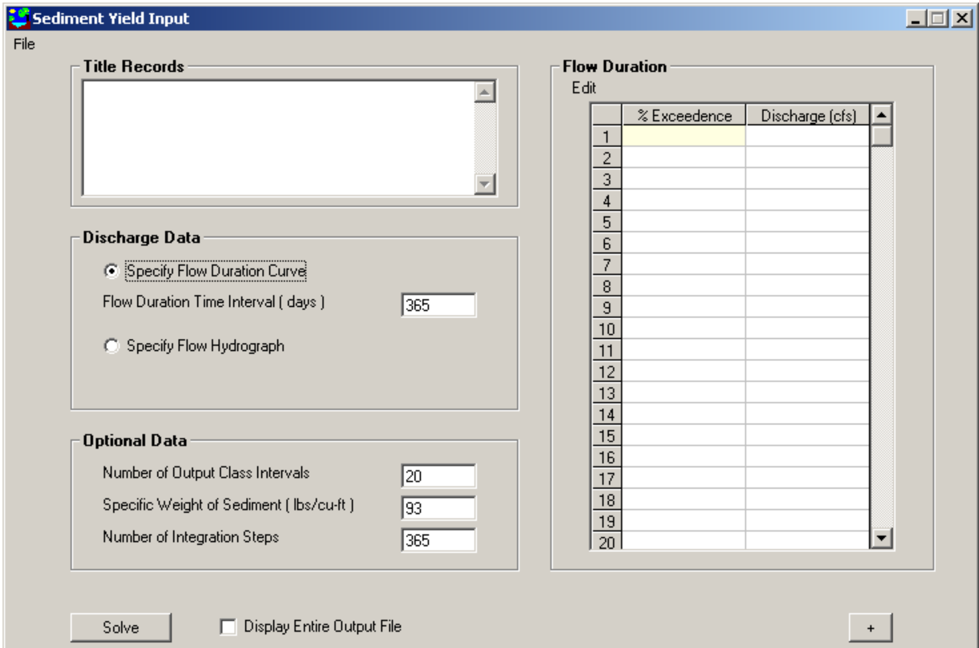

Figure 9. The Sediment Yield Input window for flow duration curve data.

References

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